Final Report for NASA IUE grant NAG5-1434

PI: Daniel E. Welty
Institution: University of Chicago
5801 S. Ellis Ave.
Chicago, IL 60637
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Grant NAG5-1434 supported four separate *IUE* observing programs, which were given a total of 10 US2 shifts during episodes 13 through 16 (Table 1). These four programs were devoted primarily to acquiring low-dispersion spectra of early type stars in various interstellar environments, in order to determine the interstellar extinction curves in those environments. The extinction curves typically are compared with information provided by other studies of the absorption and emission properties of the interstellar clouds along those lines of sight, in order to better understand the environment, physical conditions, and chemistry of the clouds. A number of the lines of sight chosen for study are characterized by extremes in either far-UV extinction, molecular or atomic abundances, or color excess - in an attempt to better discern the sometimes subtle interrelationships among those quantities.

IMMDW and EXNDW - UV Extinction in High-Latitude Clouds

Programs IMMDW and EXNDW studied the extinction properties of interstellar clouds seen at high Galactic latitudes, which are particularly suited for comparative studies of emission and absorption, since there is less of the usual foreground-background confusion as is common for clouds in the Galactic plane. The high-latitude clouds thus provide excellent tests for comprehensive models of interstellar clouds.

HD 210121, the primary target for program IMMDW, is a B3 V star located some distance behind a high-latitude molecular cloud seen in CO and IR emission. The six low-dispersion exposures obtained for this star yielded a well-determined extinction curve for the full range 1250-3250 Å ; the extinction toward this star is characterized by a somewhat weak 2175 Å bump and by a far-UV rise that is among the steepest known. The extinction curve, together with high-resolution optical and UV absorption-line spectra and with available H I 21 cm and *IRAS* emission data, provided significant constraints for chemical models of this cloud (Welty & Fowler 1992, ApJ, 393, 193). In particular, the steep far-UV extinction and the reduced ambient radiation field inferred from the IR emission may help to explain the relatively large observed abundances of CN and CO - photodissociation, primarily due to far-UV photons for these two species, is likely significantly reduced in this particular cloud. Further investigations of the physical properties

of this line of sight are being carried out with the *HST* GHRS.

In order to determine whether the extremely steep far-UV extinction found for HD 210121 was typical of the high-latitude clouds, and accounted at least in part for their molecular abundances, in program EXNDW we obtained low-dispersion spectra of 12 additional moderately reddened stars located near other high-latitude clouds. Preliminary indications are that the high-latitude clouds exhibit a range of far-UV extinction characteristics, just as for clouds in the Galactic plane, however. With this larger sample, we could also begin to look for correlations between extinction properties (size and width of the 2175 Å bump, strength of far-UV rise) and other properties (e.g., IR colors, A_V, molecular abundances) - in order to better understand the mixture of grain populations (i.e., large grains, small grains, PAH's, etc.) conjectured to be necessary to produce the observed extinction and emission. Boulanger, Prevot, & Gry (1994, A&A, 284, 956) have recently published a very similar study, based largely on stars in the Chamaeleon complex. Somewhat surprisingly, they found an anticorrelation between the strength of the emission at 12 and 25 μm (vs. that at 100 μm) and the strength of the far-UV extinction - both of which had been assumed to be due to very small grains and/or PAH's. Comparison of extinction characteristics and IR colors (using the recently available ISSA data) for lines of sight observed in our several programs will provide a significantly larger sample of lines of sight, sampling a number of different regions - and thus a very useful check on the Boulanger et al. results.

High dispersion spectra of the star HD 24263, located near the high-latitude cloud MBM 18, should provide both reasonably accurate abundances/depletions for a number of elements and some indication of the local pressure (from the C I fine structure excitation) - which have not previously been determined for any of the MBM clouds.

UVODW - Studies of Unusual Far-UV Extinction

Program UVODW had two somewhat different objectives. The first was to compare the UV extinction characteristics and interstellar abundances/depletions for lines of sight showing evidence of significant grain disruption, as theoretical studies had suggested that grain destruction would lead to a noticeable steepening of the far-UV extinction curve (as well as to reduced depletions). We chose four lines of sight, characterized by large ratios of Ca II/Na I and/or "extreme" physical conditions, in the region of the Vela supernova remnant; some additional lines of sight in other regions were available in the *IUE* archive. One of the stars, HD 72127 A, is both particularly interesting, in that it shows variable interstellar absorption and a quite large Ca II/Na I ratio, and particularly challenging to observe with *IUE*, as it has a companion ~4.5 arcsec away (which shows quite different interstellar absorption-line profiles). Separation of the spectra of the two

components, necessary for deriving extinction curves for the individual stars, will require special extraction routines such as those recently developed by B. Altner. A detailed study of the line of sight to HD 72127 A, using spectra obtained with the *HST* GHRS and with the AAT, is currently in progress.

The second objective of program UVODW was to obtain extinction curves for four stars having somewhat "anomalous" molecular abundances and/or far-UV extinction behavior (suggested by earlier TD-1 data), for a study comparing far-UV extinction (extremely steep or extremely shallow) with the abundances of various molecules and trace neutral atomic species along ~30 lines of sight. High resolution (Δv = 0.3-3.0 km s^{-1}) optical spectra of Na I, K I, Ca II, CH, CN, and CH^+ are being used to interpret UV spectra (*IUE* and/or *HST* GHRS) - in order to obtain accurate abundances from the UV spectra, which do not resolve the complex component structure seen in the higher resolution optical spectra. The goal of this project (still in progress) is to disentangle the effects of the ambient radiation field, the grain scattering properties, and the depletions - in order to characterize those properties and to provide more stringent constraints for models of interstellar cloud structure and chemistry.

ICPDW - UV Studies of Translucent Interstellar Clouds

The primary objective of program ICPDW was to obtain accurate UV extinction curves for a number of more heavily reddened stars with E(B-V) $\gtrsim$ 0.7, for which molecular absorption-line data also were available, in order to further explore the interrelationships among grain parameters, radiation fields, and molecular abundances. These somewhat thicker clouds are intermediate between the diffuse clouds, where photochemistry dominates, and the denser molecular clouds, which are dominated by gas-phase chemical reactions. The spectra obtained in this program (which are still to be analyzed) will approximately double the available sample of extinction curves for such lines of sight.

We also obtained several high-dispersion LWP spectra of the heavily reddened star HD 169454 [E(B-V) = 1.1], which lies (far) behind a cloud which exhibits strong absorption from CN and CH, and from which CS emission also has been observed. When combined with several similar spectra in the *IUE* archive, these spectra should provide significant limits on the abundances of such molecules as CS and OH for that translucent cloud; the molecular abundances will provide information on the sulfur chemistry, radiation field, and grain surface chemistry. That line of sight also shows absorption from high-velocity material ($v_{LSR} \sim +90$ km s^{-1}) which has a surprisingly small ratio of Ca II/Na I; the UV data (Mg II, Fe II, Mg I) are being used to assess the physical conditions and degree of depletion in these clouds.

Remote Observing

We note that most of the *IUE* spectra for these programs were obtained remotely, at the University of Chicago, using an IRAF-based alternative (developed by D. Welty, M. Crawford, and D. York at Chicago) to the *IUE* project's IDL-based remote observing software. The experience gained during the observations was used to test and refine the IRAF-based package; that package was subsequently delivered to the *IUE* project for distribution to other researchers desiring to observe from their home institutions.

Publications:

Welty, D.E., & Fowler, J.R. 1992, ApJ, 393, 193, "Ultraviolet, Optical, and Infrared Observations of the High-Latitude Molecular Cloud toward HD 210121"

Table 1 - NAG5-1434 Programs

IUE Year	Period	Program	Title	Shifts	Stars	Spectra Obtained SWP lo/hi	LWP lo/hi
13	9/1/90-8/31/91	IMMDW	UV Extinction in HLC's	1 US2	2	4/2	4/1
14	9/1/91-8/31/92	EXNDW	UV Extinction in HLC's	3 US2	12	17/2	17/0
15	9/1/92-8/31/93	UVODW	Unusual Far-UV Extinction	3 US2	8	13/1	20/0
16	2/1/94-1/31/95	ICPDW	Translucent IS Clouds	3 US2	9	9/0	14/2